EXHIBIT 5

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Lainema

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(45) **Date of Patent: May 12, 2009**

(54) **METHOD FOR CODING MOTION IN A VIDEO SEQUENCE**

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(51) **Int. Cl.**
H04N 5/91 (2006.01)

(52) **U.S. Cl.** **386/111**; 386/112

(58) **Field of Classification Search** 386/68, 386/111, 112, 95; 348/466, 699; 375/240.15
See application file for complete search history.

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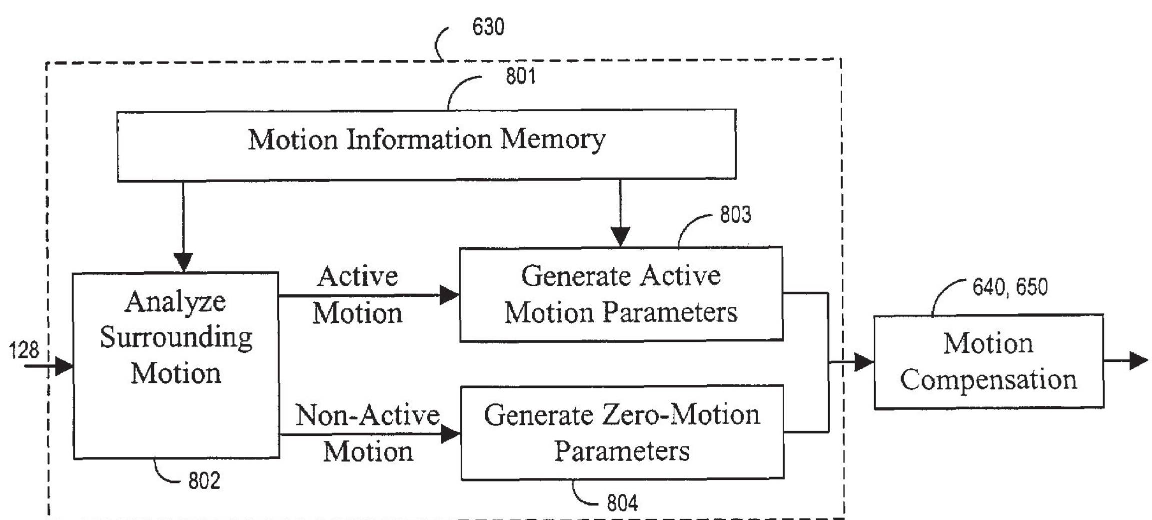
(57) **ABSTRACT**

A method of motion-compensated video encoding that enables a video sequence with a global motion component to be encoded in an efficient manner. A video encoder is arranged to assign macroblocks to be coded to specific coding modes including a skip mode, which is used to indicate one of two possible types of macroblock motion: a) zero motion, or b) global or regional motion. As each macroblock is encoded, a previously encoded region surrounding the macroblock is examined and the characteristics of motion in that region determined. With the skip mode, the macroblock to be coded and a motion vector describing the global motion or regional motion is associated with the macroblock if the motion in the region is characteristic of global motion or regional motion. If the region exhibits an insignificant level of motion, a zero valued motion vector is associated with the macroblock.

65 Claims, 10 Drawing Sheets



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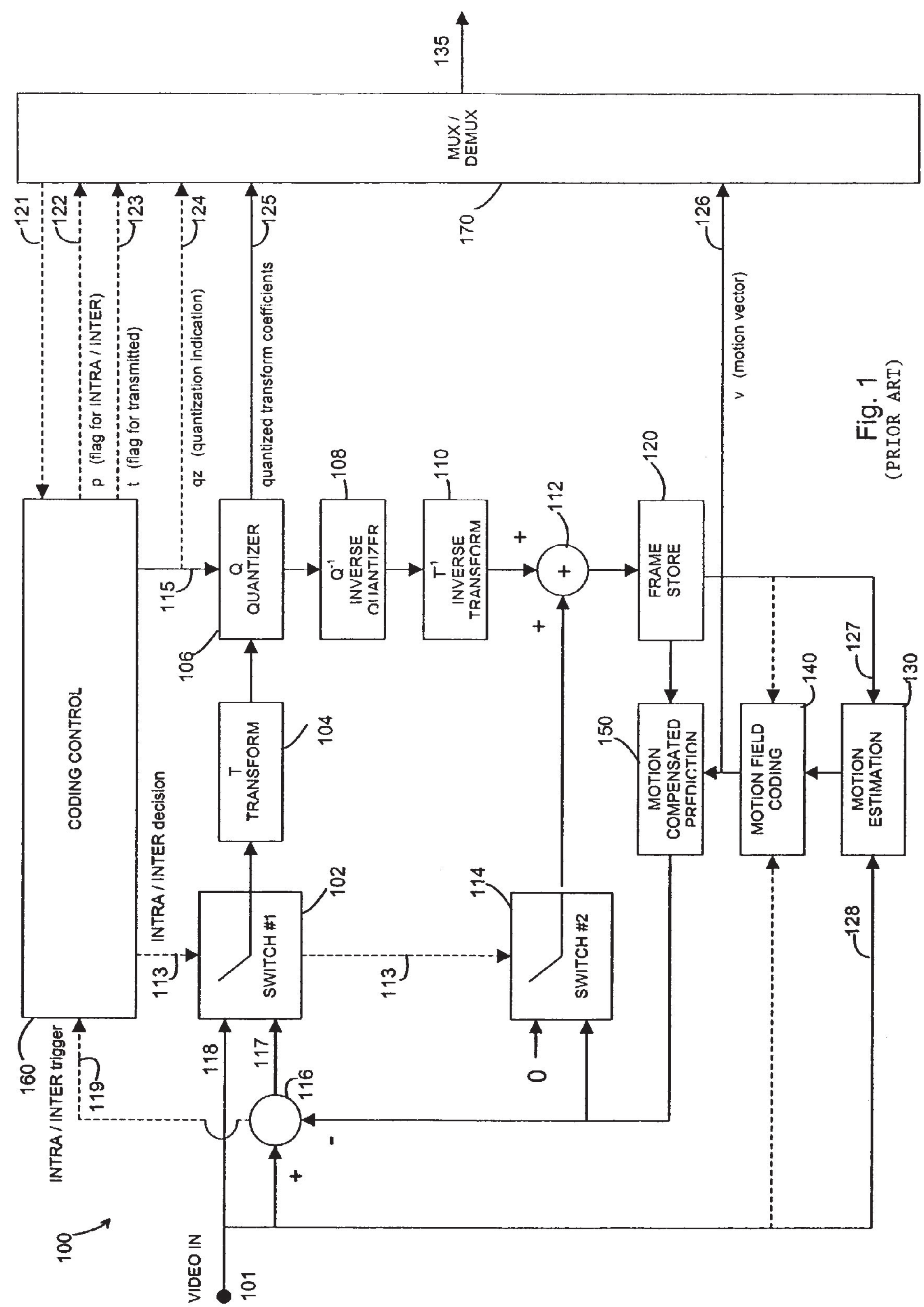


Fig. 1
(PRIOR ART)

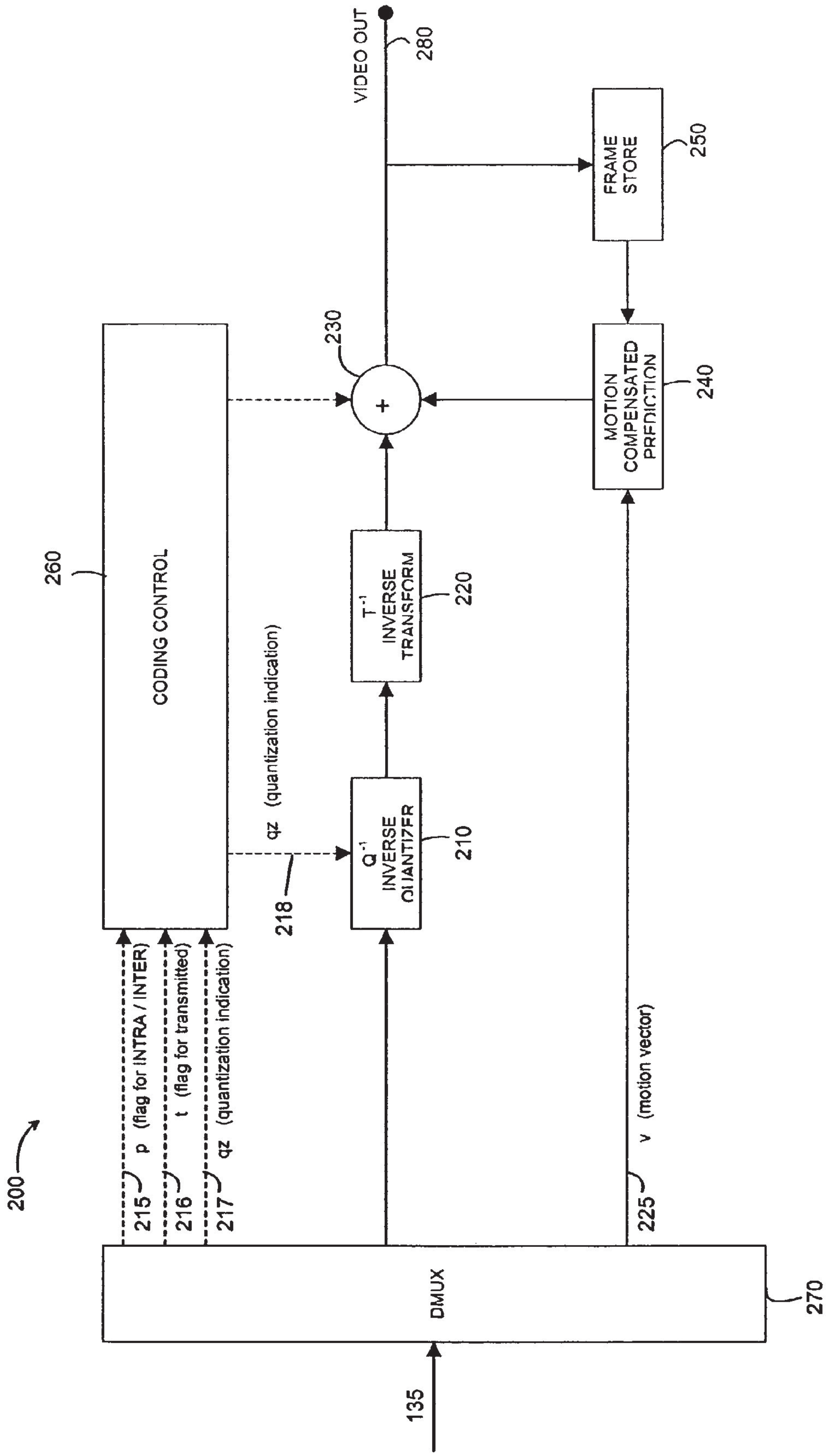
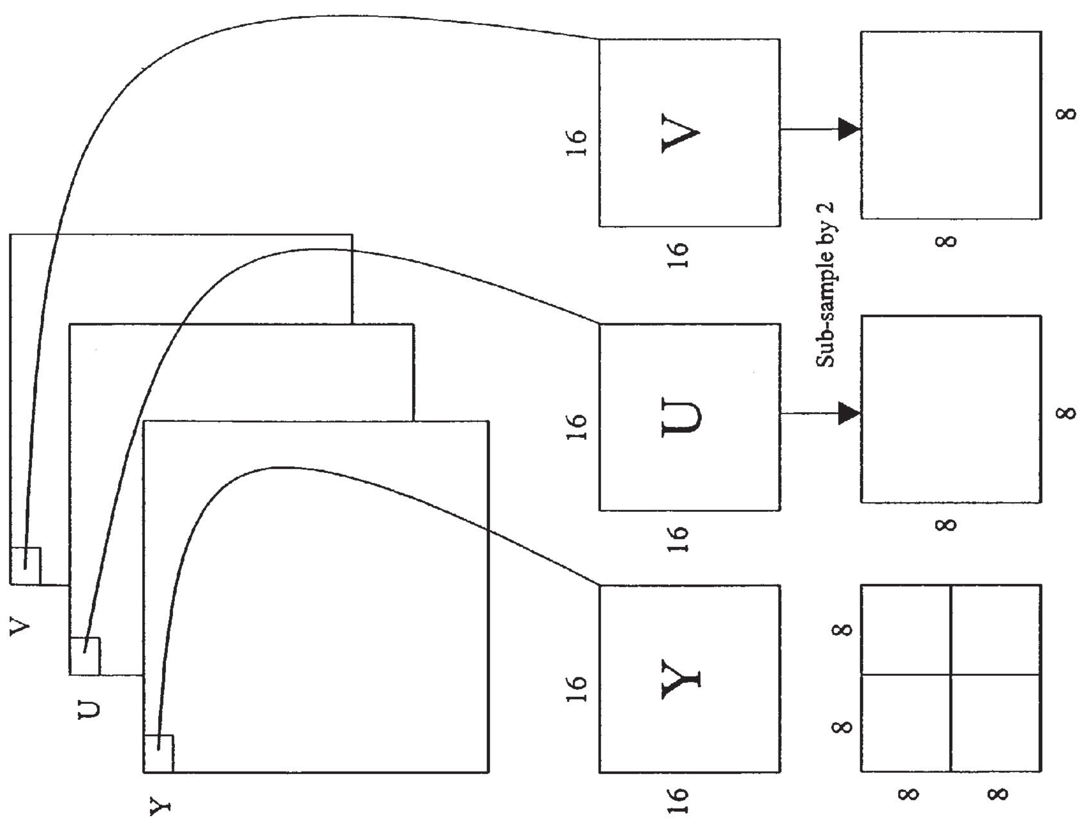


Fig. 2
(PRIOR ART)

Figure 3
(PRIOR ART)



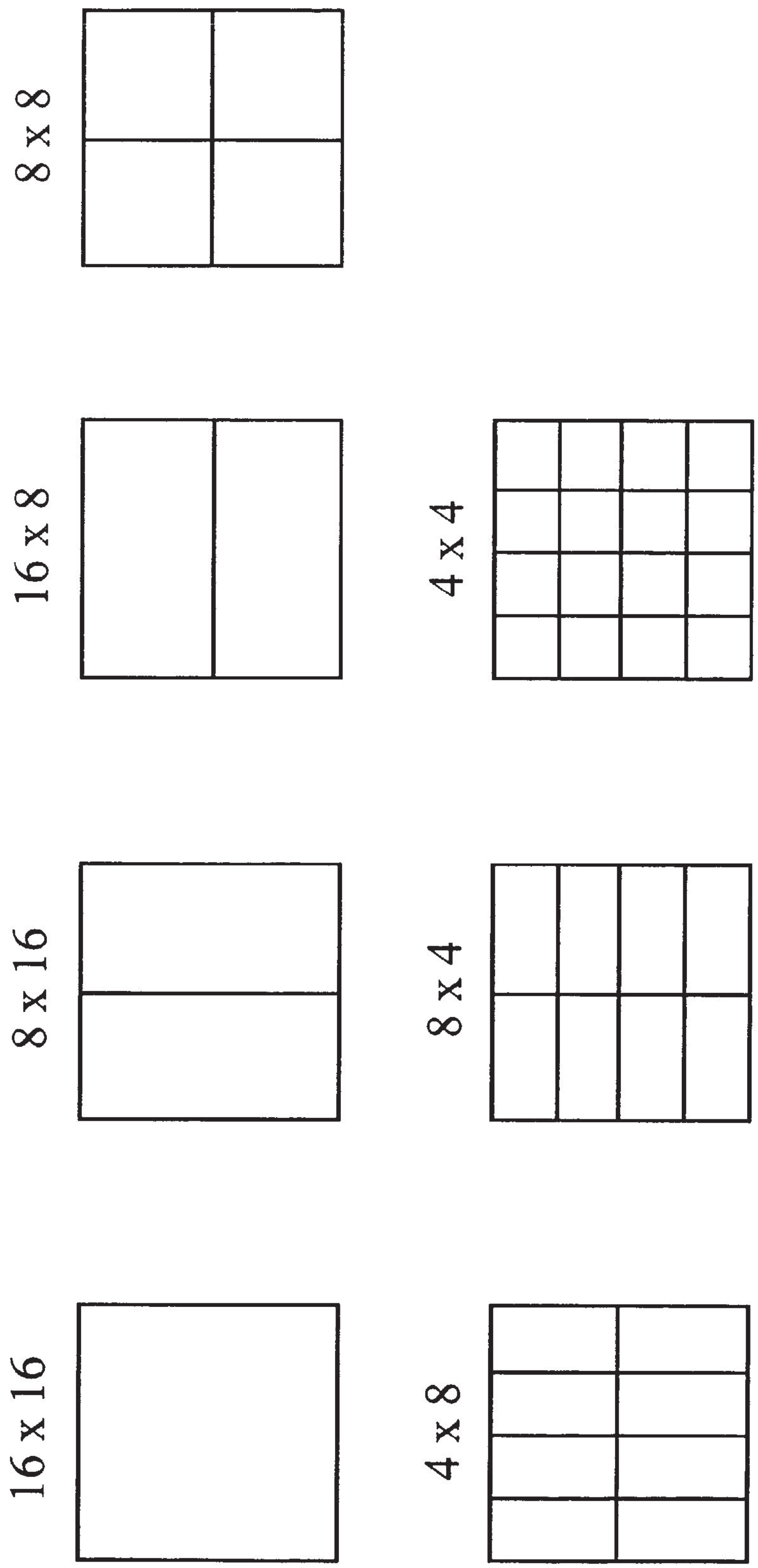


FIG. 4

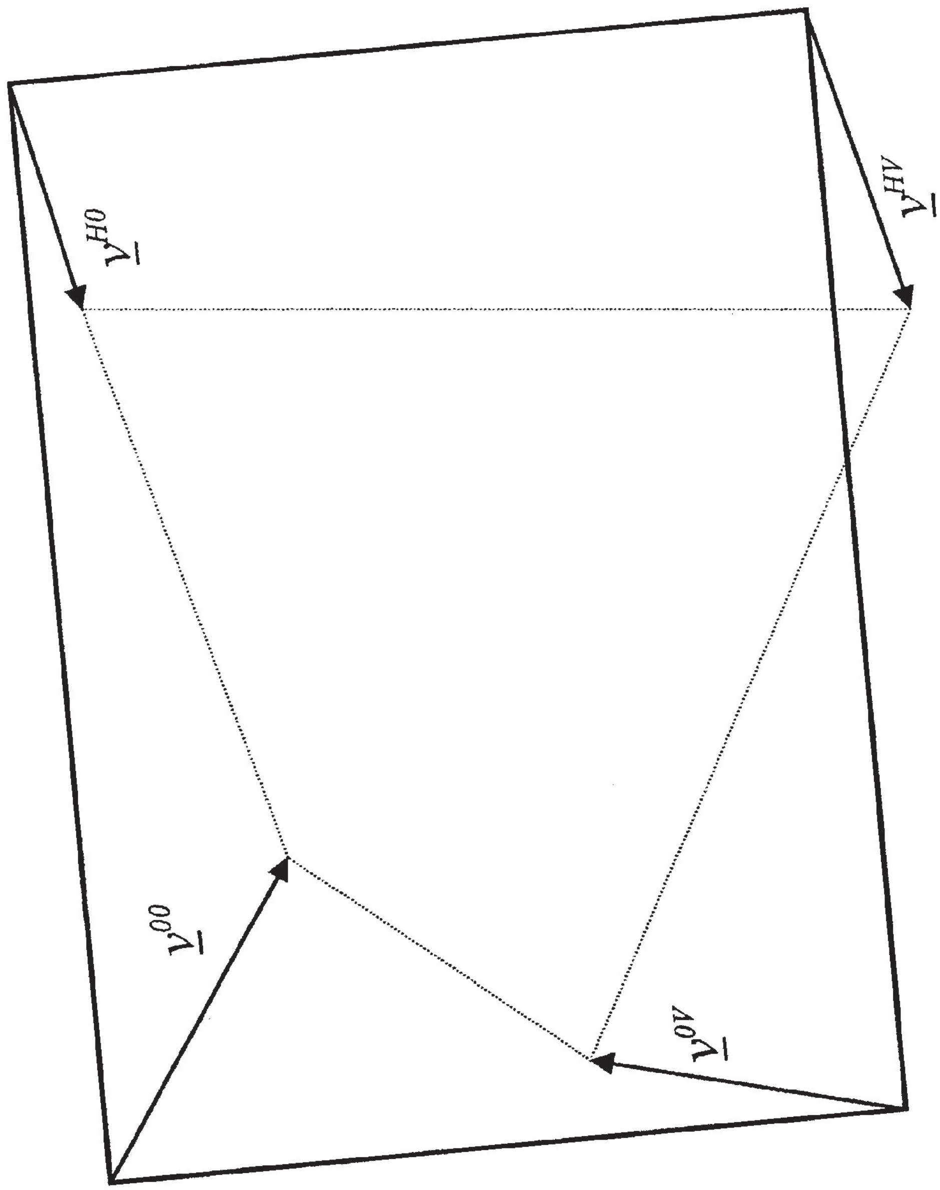


FIG. 5

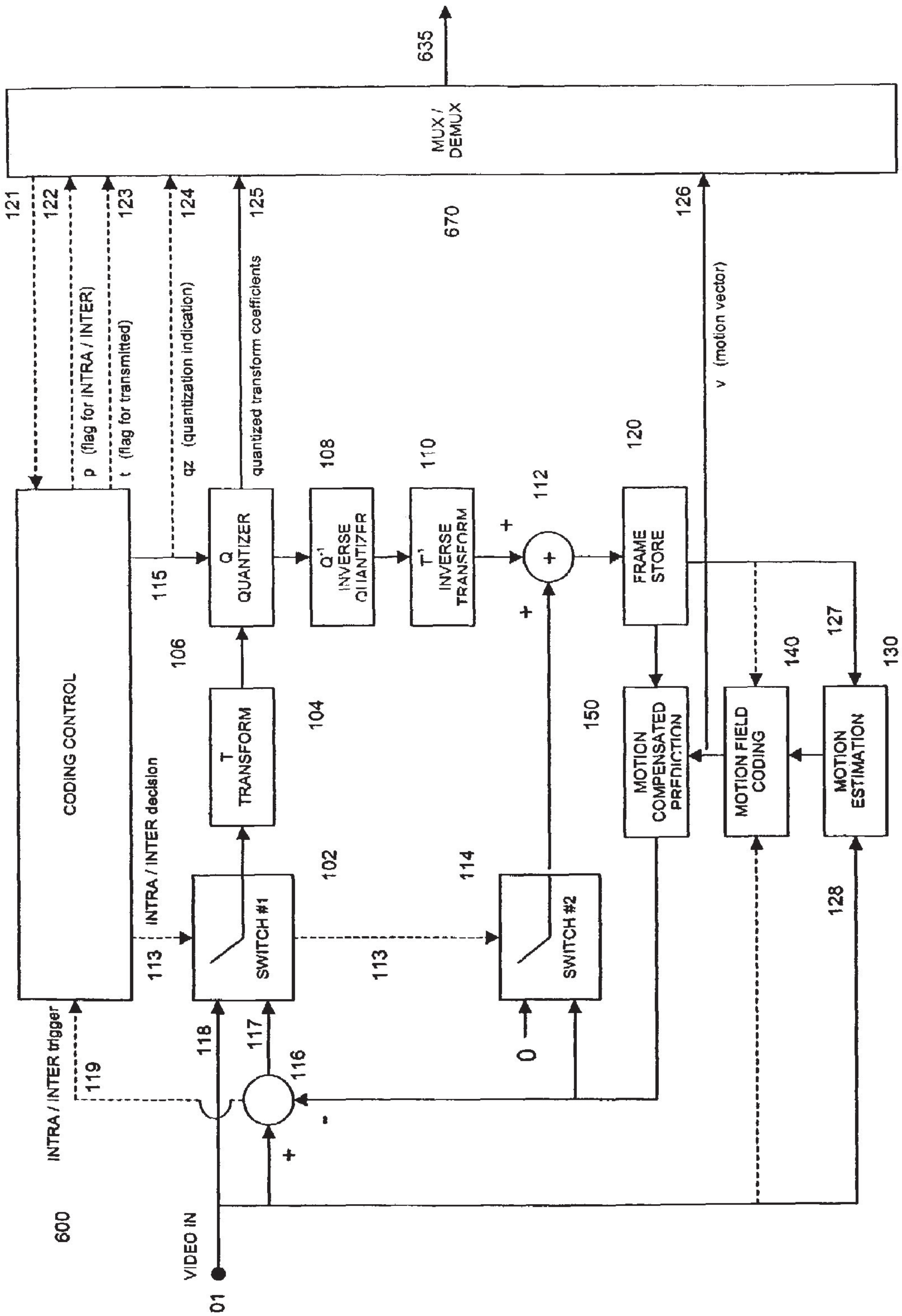

635
MUX / DEMUX
670
121
122
123
124
125
126
p (flag for INTRA / INTER)
t (flag for transmitted)
qz (quantization indication)
quantized transform coefficients
v (motion vector)
160
CODING CONTROL
Q QUANTIZER
108
Q^{-1} INVERSE QUANTIZER
110
T^{-1} INVERSE TRANSFORM
112
120
FRAME STORE
115
106
T TRANSFORM
104
INTRA / INTER decision
113
SWITCH #1
102
114
SWITCH #2
150
MOTION COMPENSATED PREDICTION
140
MOTION FIELD CODING
127
130
MOTION ESTIMATION
128
INTRA / INTER trigger
119
118
117
116
0
600
VIDEO IN
101

FIG. 6

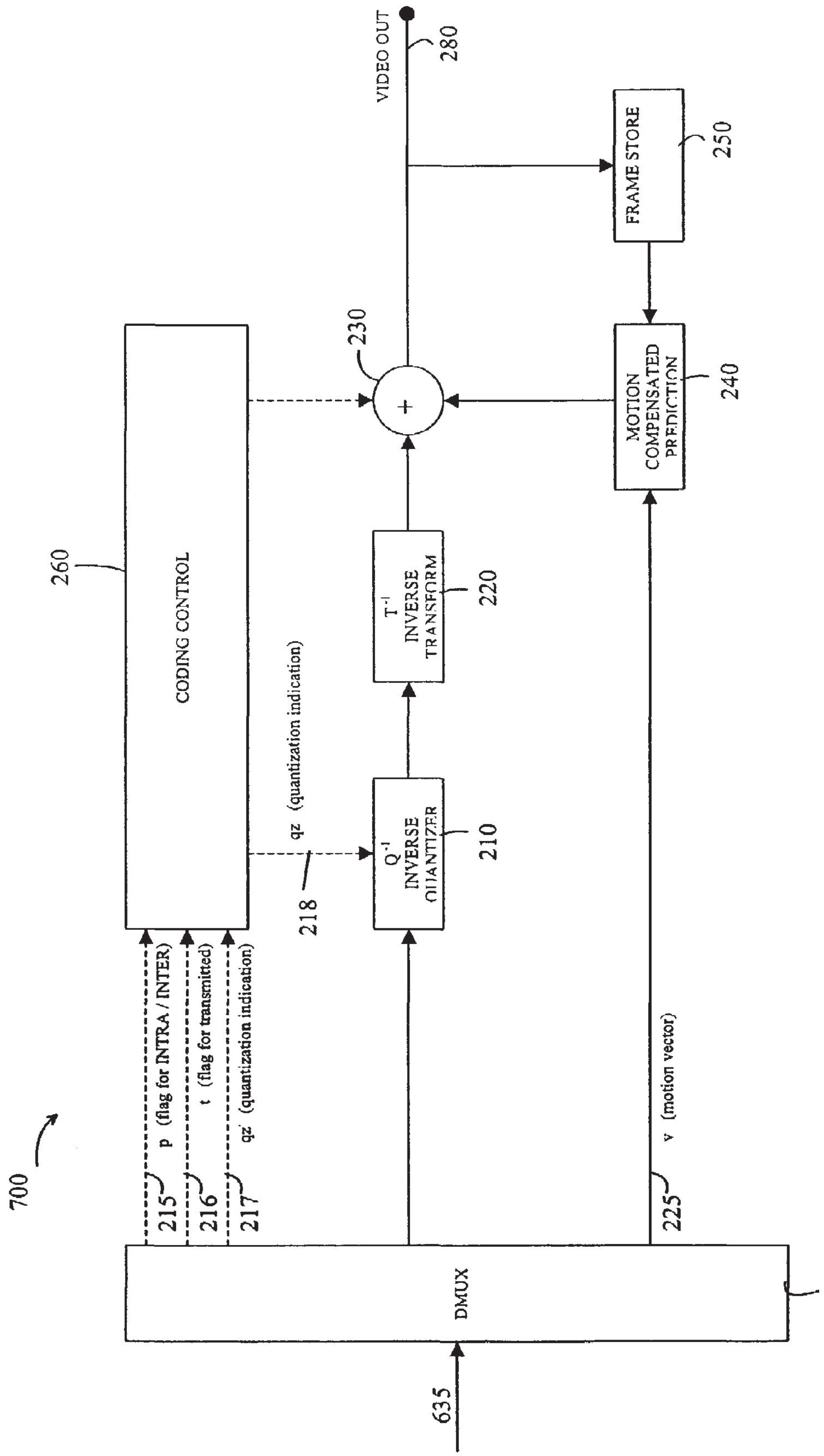

700
635
DMUX
770
215
216
217
225
p (flag for INTRA / INTER)
t (flag for transmitted)
qz' (quantization indication)
v (motion vector)
260
CODING CONTROL
qz (quantization indication)
218
Q-1 INVERSE QUANTIZER
210
T-1 INVERSE TRANSFORM
220
230
+
MOTION COMPENSATED PREDICTION
240
FRAME STORE
250
VIDEO OUT
280

Fig. 7

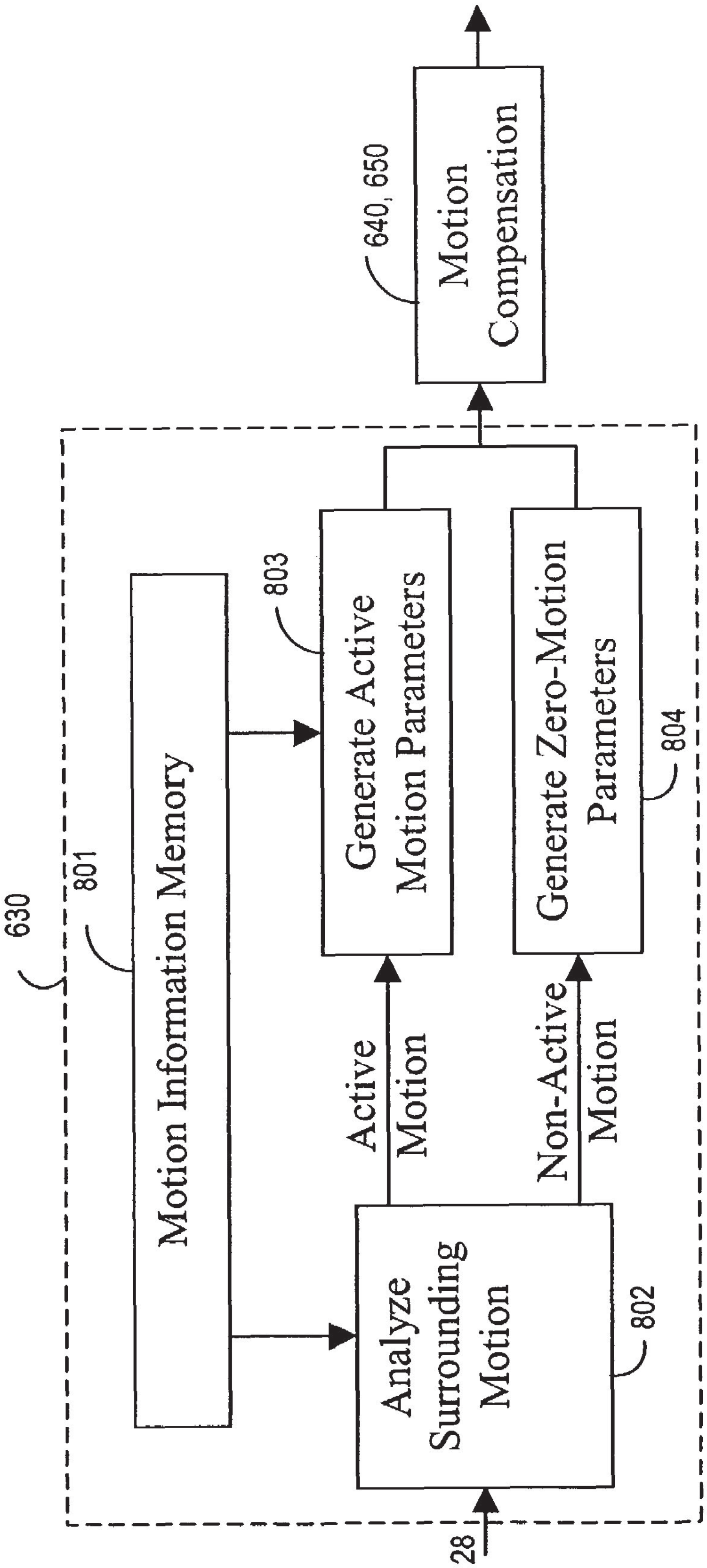

640, 650
Motion Compensation
630
801
Motion Information Memory
803
Generate Active Motion Parameters
Generate Zero-Motion Parameters
804
Active Motion
Non-Active Motion
Analyze Surrounding Motion
802
128

FIG. 8

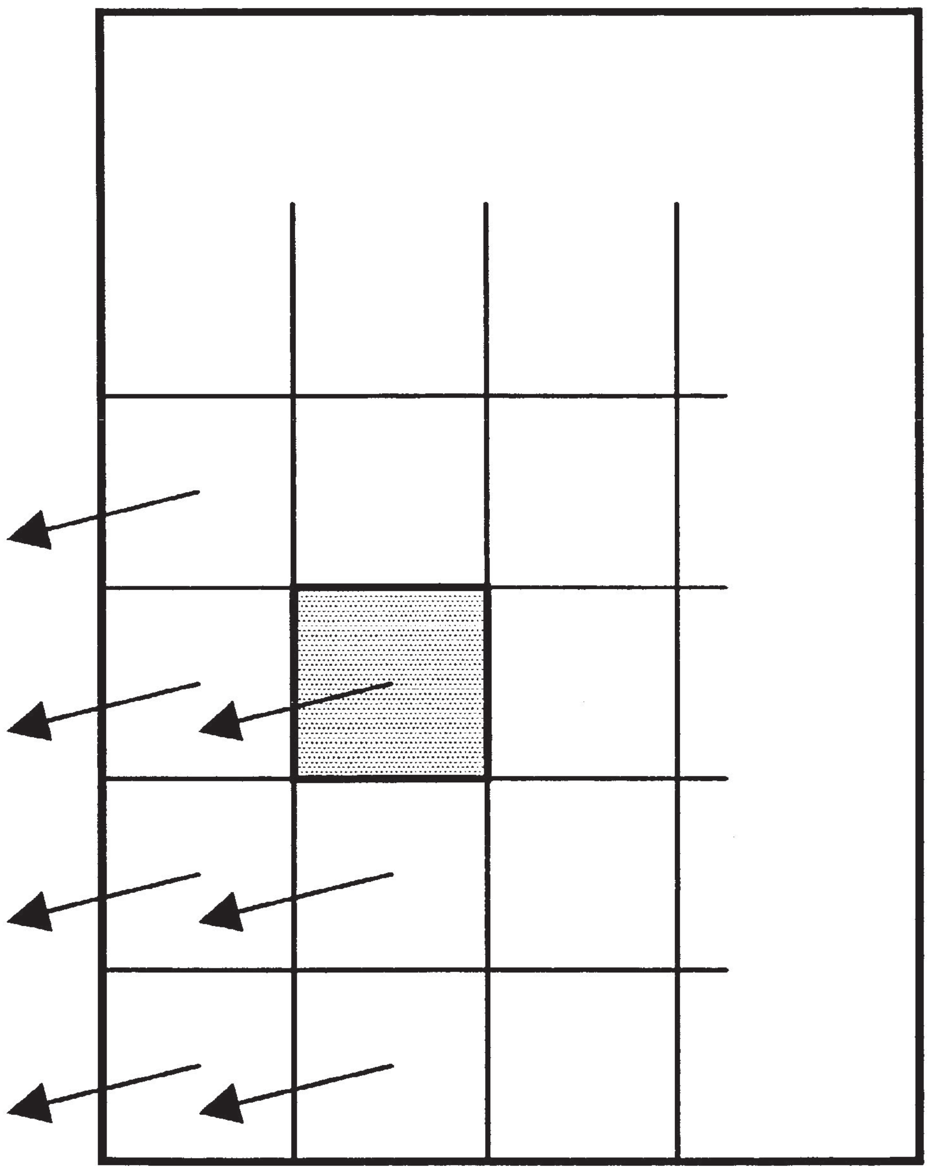


FIG. 9

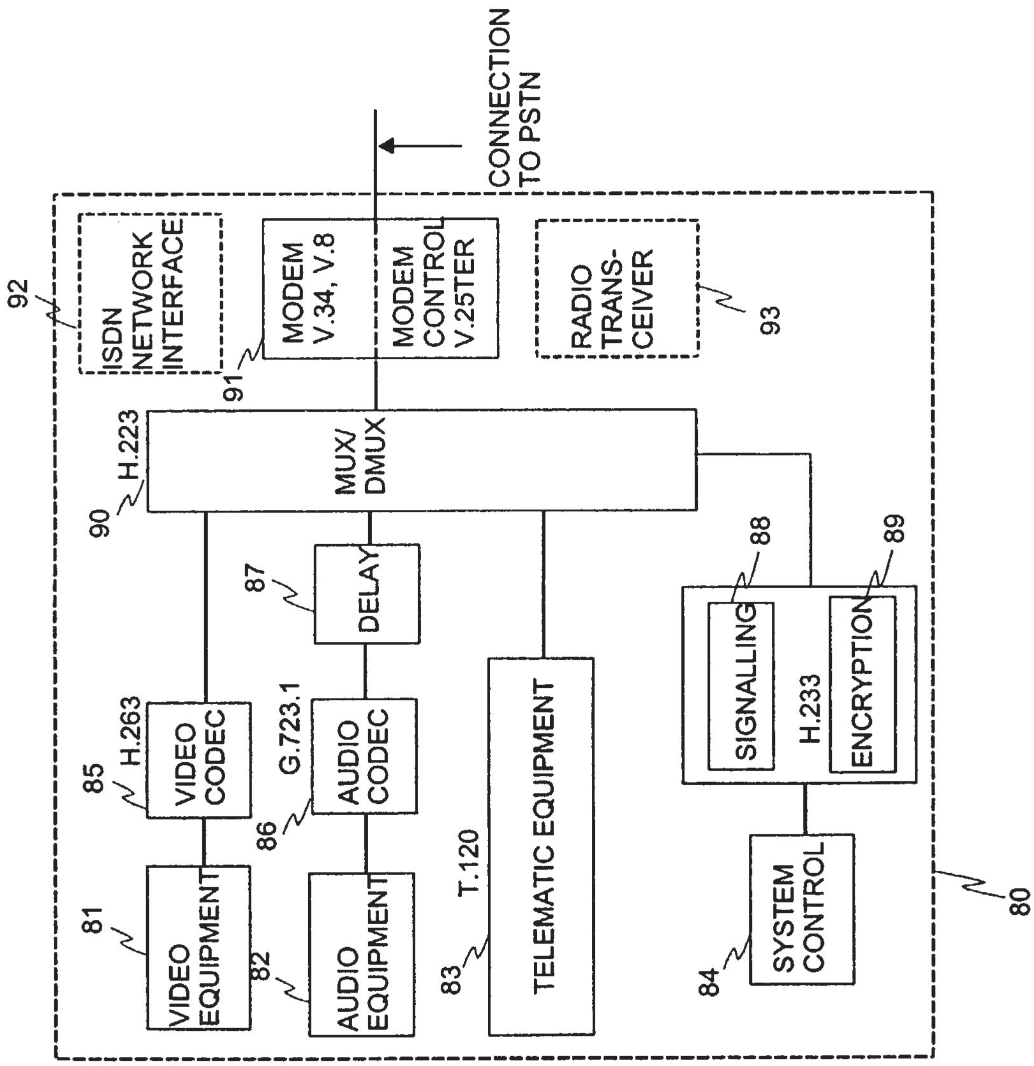

CONNECTION TO PSTN
92
ISDN NETWORK INTERFACE
91
MODEM V.34, V.8
MODEM CONTROL V.25TER
RADIO TRANS-CEIVER
93
90
H.223
MUX/ DMUX
87
DELAY
88
89
SIGNALLING
H.233
ENCRYPTION
85
H.263
VIDEO CODEC
86
G.723.1
AUDIO CODEC
81
VIDEO EQUIPMENT
82
AUDIO EQUIPMENT
83
T.120
TELEMATIC EQUIPMENT
84
SYSTEM CONTROL
80

Fig. 10

METHOD FOR CODING MOTION IN A VIDEO SEQUENCE

This application claims the benefit of U.S. Provisionl Application No. 60/365,072 filed Mar. 15, 2002.

FIELD OF THE INVENTION

The invention relates generally to communication systems and more particularly to motion compensation in video coding.

BACKGROUND OF THE INVENTION

A digital video sequence, like an ordinary motion picture recorded on film, comprises a sequence of still images, the illusion of motion being created by displaying consecutive images of the sequence one after the other at a relatively fast rate, typically 15 to 30 frames per second. Because of the relatively fast frame display rate, images in consecutive frames tend to be quite similar and thus contain a considerable amount of redundant information. For example, a typical scene may comprise some stationary elements, such as background scenery, and some moving areas, which may take many different forms, for example the face of a newsreader, moving traffic and so on. Alternatively, or additionally, so-called “global motion” may be present in the video sequence, for example due to translation, panning or zooming of the camera recording the scene. However, in many cases, the overall change between one video frame and the next is rather small.

Each frame of an uncompressed digital video sequence comprises an array of image pixels. For example, in a commonly used digital video format, known as the Quarter Common Interchange Format (QCIF), a frame comprises an array of 176×144 pixels, in which case each frame has 25,344 pixels. In turn, each pixel is represented by a certain number of bits, which carry information about the luminance and/or color content of the region of the image corresponding to the pixel. Commonly, a so-called YUV color model is used to represent the luminance and chrominance content of the image. The luminance, or Y, component represents the intensity (brightness) of the image, while the color content of the image is represented by two chrominance or color difference components, labelled U and V.

Color models based on a luminance/chrominance representation of image content provide certain advantages compared with color models that are based on a representation involving primary colors (that is Red, Green and Blue, RGB). The human visual system is more sensitive to intensity variations than it is to color variations and YUV color models exploit this property by using a lower spatial resolution for the chrominance components (U, V) than for the luminance component (Y). In this way, the amount of information needed to code the color information in an image can be reduced with an acceptable reduction in image quality.

The lower spatial resolution of the chrominance components is usually attained by spatial sub-sampling. Typically, each frame of a video sequence is divided into so-called “macroblocks”, which comprise luminance (Y) information and associated (spatially sub-sampled) chrominance (U, V) information. FIG. **3** illustrates one way in which macroblocks can be formed. FIG. **3***a* shows a frame of a video sequence represented using a YUV color model, each component having the same spatial resolution. Macroblocks are formed by representing a region of 16×16 image pixels in the original image (FIG. **3***b*) as four blocks of luminance information, each luminance block comprising an 8×8 array of luminance (Y) values and two spatially corresponding chrominance components (U and V) which are sub-sampled by a factor of two in the horizontal and vertical directions to yield corresponding arrays of 8×8 chrominance (U, V) values (see FIG. **3***c*).

A QCIF image comprises 11×9 macroblocks. If the luminance blocks and chrominance blocks are represented with 8 bit resolution (that is by numbers in the range 0 to 255), the total number of bits required per macroblock is (16×16×8)+2×(8×8×8)=3072 bits. The number of bits needed to represent a video frame in QCIF format is thus 99×3072=304,128 bits. This means that the amount of data required to transmit/record/display an uncompressed video sequence in QCIF format, represented using a YUV color model, at a rate of 30 frames per second, is more than 9 Mbps (million bits per second). This is an extremely high data rate and is impractical for use in video recording, transmission and display applications because of the very large storage capacity, transmission channel capacity and hardware performance required.

If video data is to be transmitted in real-time over a fixed line network such as an ISDN (Integrated Services Digital Network) or a conventional PSTN (Public Switched Telephone Network), the available data transmission bandwidth is typically of the order of 64 kbits/s. In mobile videotelephony, where transmission takes place at least in part over a radio communications link, the available bandwidth can be as low as 20 kbits/s. This means that a significant reduction in the amount of information used to represent video data must be achieved in order to enable transmission of digital video sequences over low bandwidth communication networks. For this reason, video compression techniques have been developed which reduce the amount of information transmitted while retaining an acceptable image quality.

Video compression methods are based on reducing the redundant and perceptually irrelevant parts of video sequences. The redundancy in video sequences can be categorised into spatial, temporal and spectral redundancy. “Spatial redundancy” is the term used to describe the correlation (similarity) between neighbouring pixels within a frame. The term “temporal redundancy” expresses the fact that objects appearing in one frame of a sequence are likely to appear in subsequent frames, while “spectral redundancy” refers to the correlation between different color components of the same image.

Sufficiently efficient compression cannot usually be achieved by simply reducing the various forms of redundancy in a given sequence of images. Thus, most current video encoders also reduce the quality of those parts of the video sequence which are subjectively the least important. In addition, the redundancy of the compressed video bit-stream itself is reduced by means of efficient loss-less encoding. Generally, this is achieved using a technique known as entropy coding.

There is often a significant amount of spatial redundancy between the pixels that make up each frame of a digital video sequence. In other words, the value of any pixel within a frame of the sequence is substantially the same as the value of other pixels in its immediate vicinity. Typically, video coding systems reduce spatial redundancy using a technique known as “block-based transform coding”, in which a mathematical transformation, such as a two-dimensional Discrete Cosine Transform (DCT), is applied to blocks of image pixels. This transforms the image data from a representation comprising pixel values to a form comprising a set of coefficient values representative of spatial frequency components significantly

reducing spatial redundancy and thereby producing a more compact representation of the image data.

Frames of a video sequence which are compressed using block-based transform coding, without reference to any other frame within the sequence, are referred to as INTRA-coded or I-frames. Additionally, and where possible, blocks of INTRA-coded frames are predicted from previously coded blocks within the same frame. This technique, known as INTRA-prediction, has the effect of further reducing the amount of data required to represent an INTRA-coded frame.

Generally, video coding systems not only reduce the spatial redundancy within individual frames of a video sequence, but also make use of a technique known as "motion-compensated prediction", to reduce the temporal redundancy in the sequence. Using motion-compensated prediction, the image content of some (often many) frames in a digital video sequence is "predicted" from one or more other frames in the sequence, known as "reference" frames. Prediction of image content is achieved by tracking the motion of objects or regions of an image between a frame to be coded (compressed) and the reference frame(s) using "motion vectors". In general, the reference frame(s) may precede the frame to be coded or may follow it in the video sequence. As in the case of INTRA-coding, motion compensated prediction of a video frame is typically performed macroblock-by-macroblock.

Frames of a video sequence which are compressed using motion-compensated prediction are generally referred to as INTER-coded or P-frames. Motion-compensated prediction alone rarely provides a sufficiently precise representation of the image content of a video frame and therefore it is typically necessary to provide a so-called "prediction error" (PE) frame with each INTER-coded frame. The prediction error frame represents the difference between a decoded version of the INTER-coded frame and the image content of the frame to be coded. More specifically, the prediction error frame comprises values that represent the difference between pixel values in the frame to be coded and corresponding reconstructed pixel values formed on the basis of a predicted version of the frame in question. Consequently, the prediction error frame has characteristics similar to a still image and block-based transform coding can be applied in order to reduce its spatial redundancy and hence the amount of data (number of bits) required to represent it.

In order to illustrate the operation of a generic video coding system in greater detail, reference will now be made to the exemplary video encoder and video decoder illustrated in FIGS. **1** and **2** of the accompanying drawings. The video encoder **100** of FIG. **1** employs a combination of INTRA- and INTER-coding to produce a compressed (encoded) video bit-stream and decoder **200** of FIG. **2** is arranged to receive and decode the video bit-stream produced by encoder **100** in order to produce a reconstructed video sequence. Throughout the following description it will be assumed that the luminance component of a macroblock comprises 16×16 pixels arranged as an array of 4, 8×8 blocks, and that the associated chrominance components are spatially sub-sampled by a factor of two in the horizontal and vertical directions to form 8×8 blocks, as depicted in FIG. **3**. Extension of the description to other block sizes and other sub-sampling schemes will be apparent to those of ordinary skill in the art.

The video encoder **100** comprises an input **101** for receiving a digital video signal from a camera or other video source (not shown). It also comprises a transformation unit **104** which is arranged to perform a block-based discrete cosine transform (DCT), a quantizer **106**, an inverse quantizer **108**, an inverse transformation unit **110**, arranged to perform an inverse block-based discrete cosine transform (IDCT), combiners **112** and **116**, and a frame store **120**. The encoder further comprises a motion estimator **130**, a motion field coder **140** and a motion compensated predictor **150**. Switches **102** and **114** are operated co-operatively by control manager **160** to switch the encoder between an INTRA-mode of video encoding and an INTER-mode of video encoding. The encoder **100** also comprises a video multiplex coder **170** which forms a single bit-stream from the various types of information produced by the encoder **100** for further transmission to a remote receiving terminal or, for example, for storage on a mass storage medium, such as a computer hard drive (not shown).

Encoder **100** operates as follows. Each frame of uncompressed video provided from the video source to input **101** is received and processed macroblock by macroblock, preferably in raster-scan order. When the encoding of a new video sequence starts, the first frame to be encoded is encoded as an INTRA-coded frame. Subsequently, the encoder is programmed to code each frame in INTER-coded format, unless one of the following conditions is met: 1) it is judged that the current macroblock of the frame being coded is so dissimilar from the pixel values in the reference frame used in its prediction that excessive prediction error information is produced, in which case the current macroblock is coded in INTRA-coded format; 2) a predefined INTRA frame repetition interval has expired; or 3) feedback is received from a receiving terminal indicating a request for a frame to be provided in INTRA-coded format.

The occurrence of condition 1) is detected by monitoring the output of the combiner **116**. The combiner **116** forms a difference between the current macroblock of the frame being coded and its prediction, produced in the motion compensated prediction block **150**. If a measure of this difference (for example a sum of absolute differences of pixel values) exceeds a predetermined threshold, the combiner **116** informs the control manager **160** via a control line **119** and the control manager **160** operates the switches **102** and **114** via control line **113** so as to switch the encoder **100** into INTRA-coding mode. In this way, a frame which is otherwise encoded in INTER-coded format may comprise INTRA-coded macroblocks. Occurrence of condition 2) is monitored by means of a timer or frame counter implemented in the control manager **160**, in such a way that if the timer expires, or the frame counter reaches a predetermined number of frames, the control manager **160** operates the switches **102** and **114** via control line **113** to switch the encoder into INTRA-coding mode. Condition 3) is triggered if the control manager **160** receives a feedback signal from, for example, a receiving terminal, via control line **121** indicating that an INTRA frame refresh is required by the receiving terminal. Such a condition may arise, for example, if a previously transmitted frame is badly corrupted by interference during its transmission, rendering it impossible to decode at the receiver. In this situation, the receiving decoder issues a request for the next frame to be encoded in INTRA-coded format, thus re-initialising the coding sequence.

Operation of the encoder **100** in INTRA-coding mode will now be described. In INTRA-coding mode, the control manager **160** operates the switch **102** to accept video input from input line **118**. The video signal input is received macroblock by macroblock from input **101** via the input line **118**. As they are received, the blocks of luminance and chrominance values which make up the macroblock are passed to the DCT transformation block **104**, which performs a 2-dimensional discrete cosine transform on each block of values, producing a 2-dimensional array of DCT coefficients for each block. DCT transformation block **104** produces an array of coefficient

values for each block, the number of coefficient values corresponding to the dimensions of the blocks which make up the macroblock (in this case 8×8). The DCT coefficients for each block are passed to the quantizer **106**, where they are quantized using a quantization parameter QP. Selection of the quantization parameter QP is controlled by the control manager **160** via control line **115**.

The array of quantized DCT coefficients for each block is then passed from the quantizer **106** to the video multiplex coder **170**, as indicated by line **125** in FIG. **1**. The video multiplex coder **170** orders the quantized transform coefficients for each block using a zigzag scanning procedure, thereby converting the two-dimensional array of quantized transform coefficients into a one-dimensional array. Each non-zero valued quantized coefficient in the one dimensional array is then represented as a pair of values, referred to as level and run, where level is the value of the quantized coefficient and run is the number of consecutive zero-valued coefficients preceding the coefficient in question. The run and level values are further compressed in the video multiplex coder **170** using entropy coding, for example, variable length coding (VLC), or arithmetic coding.

Once the run and level values have been entropy coded using an appropriate method, the video multiplex coder **170** further combines them with control information, also entropy coded using a method appropriate for the kind of information in question, to form a single compressed bit-stream of coded image information **135**. It should be noted that while entropy coding has been described in connection with operations performed by the video multiplex coder **170**, in alternative implementations a separate entropy coding unit may be provided.

A locally decoded version of the macroblock is also formed in the encoder **100**. This is done by passing the quantized transform coefficients for each block, output by quantizer **106**, through inverse quantizer **108** and applying an inverse DCT transform in inverse transformation block **110**. In this way a reconstructed array of pixel values is constructed for each block of the macroblock. The resulting decoded image data is input to combiner **112**. In INTRA-coding mode, switch **114** is set so that the input to the combiner **112** via switch **114** is zero. In this way, the operation performed by combiner **112** is equivalent to passing the decoded image data unaltered.

As subsequent macroblocks of the current frame are received and undergo the previously described encoding and local decoding steps in blocks **104**, **106**, **108**, **110** and **112**, a decoded version of the INTRA-coded frame is built up in frame store **120**. When the last macroblock of the current frame has been INTRA-coded and subsequently decoded, the frame store **120** contains a completely decoded frame, available for use as a motion prediction reference frame in coding a subsequently received video frame in INTER-coded format.

Operation of the encoder **100** in INTER-coding mode will now be described. In INTER-coding mode, the control manager **160** operates switch **102** to receive its input from line **117**, which comprises the output of combiner **116**. The combiner **116** receives the video input signal macroblock by macroblock from input **101**. As combiner **116** receives the blocks of luminance and chrominance values which make up the macroblock, it forms corresponding blocks of prediction error information. The prediction error information represents the difference between the block in question and its prediction, produced in motion compensated prediction block **150**. More specifically, the prediction error information for each block of the macroblock comprises a two-dimensional array of values, each of which represents the difference

between a pixel value in the block of luminance or chrominance information being coded and a decoded pixel value obtained by forming a motion-compensated prediction for the block, according to the procedure to be described below. Thus, in the exemplary video coding system considered here where each macroblock comprises, for example, an assembly of 8×8 blocks comprising luminance and chrominance values, the prediction error information for each block of the macroblock similarly comprises an 8×8 array of prediction error values.

The prediction error information for each block of the macroblock is passed to DCT transformation block **104**, which performs a two-dimensional discrete cosine transform on each block of prediction error values to produce a two-dimensional array of DCT transform coefficients for each block. DCT transformation block **104** produces an array of coefficient values for each prediction error block, the number of coefficient values corresponding to the dimensions of the blocks which make up the macroblock (in this case 8×8). The transform coefficients derived from each prediction error block are passed to quantizer **106** where they are quantized using a quantization parameter QP, in a manner analogous to that described above in connection with operation of the encoder in INTRA-coding mode. As before, selection of the quantization parameter QP is controlled by the control manager **160** via control line **115**.

The quantized DCT coefficients representing the prediction error information for each block of the macroblock are passed from quantizer **106** to video multiplex coder **170**, as indicated by line **125** in FIG. **1**. As in INTRA-coding mode, the video multiplex coder **170** orders the transform coefficients for each prediction error block using a certain zigzag scanning procedure and then represents each non-zero valued quantized coefficient as a run-level pair. It further compresses the run-level pairs using entropy coding, in a manner analogous to that described above in connection with INTRA-coding mode. Video multiplex coder **170** also receives motion vector information (described in the following) from motion field coding block **140** via line **126** and control information from control manager **160**. It entropy codes the motion vector information and control information and forms a single bit-stream of coded image information, **135** comprising the entropy coded motion vector, prediction error and control information.

The quantized DCT coefficients representing the prediction error information for each block of the macroblock are also passed from quantizer **106** to inverse quantizer **108**. Here they are inverse quantized and the resulting blocks of inverse quantized DCT coefficients are applied to inverse DCT transform block **110**, where they undergo inverse DCT transformation to produce locally decoded blocks of prediction error values. The locally decoded blocks of prediction error values are then input to combiner **112**. In INTER-coding mode, switch **114** is set so that the combiner **112** also receives predicted pixel values for each block of the macroblock, generated by motion-compensated prediction block **150**. The combiner **112** combines each of the locally decoded blocks of prediction error values with a corresponding block of predicted pixel values to produce reconstructed image blocks and stores them in frame store **120**.

As subsequent macroblocks of the video signal are received from the video source and undergo the previously described encoding and decoding steps in blocks **104**, **106**, **108**, **110**, **112**, a decoded version of the frame is built up in frame store **120**. When the last macroblock of the frame has been processed, the frame store **120** contains a completely decoded frame, available for use as a motion prediction ref-

erence frame in encoding a subsequently received video frame in INTER-coded format.

The details of the motion-compensated prediction performed by video encoder **100** will now be considered.

Any frame encoded in INTER-coded format requires a reference frame for motion-compensated prediction. This means, necessarily, that when encoding a video sequence, the first frame to be encoded, whether it is the first frame in the sequence, or some other frame, must be encoded in INTRA-coded format. This, in turn, means that when the video encoder **100** is switched into INTER-coding mode by control manager **160**, a complete reference frame, formed by locally decoding a previously encoded frame, is already available in the frame store **120** of the encoder. In general, the reference frame is formed by locally decoding either an INTRA-coded frame or an INTER-coded frame.

In the following description it will be assumed that the encoder performs motion compensated prediction on a macroblock basis, i.e. a macroblock is the smallest element of a video frame that can be associated with motion information. It will further be assumed that a prediction for a given macroblock is formed by identifying a region of 16×16 values in the luminance component of the reference frame that shows best correspondence with the 16×16 luminance values of the macroblock in question. Motion-compensated prediction in a video coding system where motion information may be associated with elements smaller than a macroblock will be considered later in the text.

The first step in forming a prediction for a macroblock of the current frame is performed by motion estimation block **130**. The motion estimation block **130** receives the blocks of luminance and chrominance values which make up the current macroblock of the frame to be coded via line **128**. It then performs a block matching operation in order to identify a region in the reference frame that corresponds best with the current macroblock. In order to perform the block matching operation, motion estimation block **130** accesses reference frame data stored in frame store **120** via line **127**. More specifically, motion estimation block **130** performs block-matching by calculating difference values (e.g. sums of absolute differences) representing the difference in pixel values between the macroblock under examination and candidate best-matching regions of pixels from a reference frame stored in the frame store **120**. A difference value is produced for candidate regions at all possible offsets within a predefined search region of the reference frame and motion estimation block **130** determines the smallest calculated difference value. The candidate region that yields the smallest difference value is selected as the best-matching region. The offset between the current macroblock and the best-matching region identified in the reference frame defines a “motion vector” for the macroblock in question. The motion vector typically comprises a pair of numbers, one describing the horizontal (Δx) between the current macroblock and the best-matching region of the reference frame, the other representing the vertical displacement (Δy).

Once the motion estimation block **130** has produced a motion vector for the macroblock, it outputs the motion vector to the motion field coding block **140**. The motion field coding block **140** approximates the motion vector received from motion estimation block **130** using a motion model comprising a set of basis functions and motion coefficients. More specifically, the motion field coding block **140** represents the motion vector as a set of motion coefficient values which, when multiplied by the basis functions, form an approximation of the motion vector. Typically, a translational motion model having only two motion coefficients and basis functions is used, but motion models of greater complexity may also be used.

The motion coefficients are passed from motion field coding block **140** to motion compensated prediction block **150**. Motion compensated prediction block **150** also receives the best-matching region of pixel values identified by motion estimation block **130** from frame store **120**. Using the approximate representation of the motion vector generated by motion field coding block **140** and the pixel values of the best-matching region of pixels from the reference frame, motion compensated prediction block **150** generates an array of predicted pixel values for each block of the current macroblock. Each block of predicted pixel values is passed to combiner **116** where the predicted pixel values are subtracted from the actual (input) pixel values in the corresponding block of the current macroblock. In this way a set of prediction error blocks for the macroblock is obtained.

Operation of the video decoder **200**, shown in FIG. **2** will now be described. The decoder **200** comprises a video multiplex decoder **270**, which receives an encoded video bit-stream **135** from the encoder **100** and demultiplexes it into its constituent parts, an inverse quantizer **210**, an inverse DCT transformer **220**, a motion compensated prediction block **240**, a frame store **250**, a combiner **230**, a control manager **260**, and an output **280**.

The control manager **260** controls the operation of the decoder **200** in response to whether an INTRA- or an INTER-coded frame is being decoded. An INTRA/INTER trigger control signal, which causes the decoder to switch between decoding modes is derived, for example, from picture type information associated with each compressed video frame received from the encoder. The INTRA/INTER trigger control signal is extracted from the encoded video bit-stream by the video multiplex decoder **270** and is passed to control manager **260** via control line **215**.

Decoding of an INTRA-coded frame is performed on a macroblock-by-macroblock basis, each macroblock being decoded substantially as soon as encoded information relating to it is received in the video bit-stream **135**. The video multiplex decoder **270** separates the encoded information for the blocks of the macroblock from possible control information relating to the macroblock in question. The encoded information for each block of an INTRA-coded macroblock comprises variable length codewords representing the entropy coded level and run values for the non-zero quantized DCT coefficients of the block. The video multiplex decoder **270** decodes the variable length codewords using a variable length decoding method corresponding to the encoding method used in the encoder **100** and thereby recovers the level and run values. It then reconstructs the array of quantized transform coefficient values for each block of the macroblock and passes them to inverse quantizer **210**. Any control information relating to the macroblock is also decoded in the video multiplex decoder **270** using an appropriate decoding method and is passed to control manager **260**. In particular, information relating to the level of quantization applied to the transform coefficients is extracted from the encoded bit-stream by video multiplex decoder **270** and provided to control manager **260** via control line **217**. The control manager, in turn, conveys this information to inverse quantizer **210** via control line **218**. Inverse quantizer **210** inverse quantizes the quantized DCT coefficients for each block of the macroblock according to the control information and provides the now inverse quantized DCT coefficients to inverse DCT transformer **220**.

Inverse DCT transformer **220** performs an inverse DCT transform on the inverse quantized DCT coefficients for each

block of the macroblock to form a decoded block of image information comprising reconstructed pixel values. The reconstructed pixel values for each block of the macroblock are passed via combiner **230** to the video output **280** of the decoder where, for example, they can be provided to a display device (not shown). The reconstructed pixel values for each block are also stored in frame store **250**. Because motion-compensated prediction is not used in the encoding/decoding of INTRA coded macroblocks control manager **260** controls combiner **230** to pass each block of pixel values as such to the video output **280** and frame store **250**. As subsequent macroblocks of the INTRA-coded frame are decoded and stored, a decoded frame is progressively assembled in the frame store **250** and thus becomes available for use as a reference frame for motion compensated prediction in connection with the decoding of subsequently received INTER-coded frames.

INTER-coded frames are also decoded macroblock by macroblock, each INTER-coded macroblock being decoded substantially as soon as encoded information relating to it is received in the bit-stream **135**. The video multiplex decoder **270** separates the encoded prediction error information for each block of an INTER-coded macroblock from encoded motion vector information and possible control information relating to the macroblock in question. As explained in the foregoing, the encoded prediction error information for each block of the macroblock comprises variable length codewords representing the entropy coded level and run values for the non-zero quantized transform coefficients of the prediction error block in question. The video multiplex decoder **270** decodes the variable length codewords using a variable length decoding method corresponding to the encoding method used in the encoder **100** and thereby recovers the level and run values. It then reconstructs an array of quantized transform coefficient values for each prediction error block and passes them to inverse quantizer **210**. Control information relating to the INTER-coded macroblock is also decoded in the video multiplex decoder **270** using an appropriate decoding method and is passed to control manager **260**. Information relating to the level of quantization applied to the transform coefficients of the prediction error blocks is extracted from the encoded bit-stream and provided to control manager **260** via control line **217**. The control manager, in turn, conveys this information to inverse quantizer **210** via control line **218**. Inverse quantizer **210** inverse quantizes the quantized DCT coefficients representing the prediction error information for each block of the macroblock according to the control information and provides the now inverse quantized DCT coefficients to inverse DCT transformer **220**. The inverse quantized DCT coefficients representing the prediction error information for each block are then inverse transformed in the inverse DCT transformer **220** to yield an array of reconstructed prediction error values for each block of the macroblock.

The encoded motion vector information associated with the macroblock is extracted from the encoded video bit-stream **135** by video multiplex decoder **270** and is decoded. The decoded motion vector information thus obtained is passed via control line **225** to motion compensated prediction block **240**, which reconstructs a motion vector for the macroblock using the same motion model as that used to encode the INTER-coded macroblock in encoder **100**. The reconstructed motion vector approximates the motion vector originally determined by motion estimation block **130** of the encoder. The motion compensated prediction block **240** of the decoder uses the reconstructed motion vector to identify the location of a region of reconstructed pixels in a prediction reference frame stored in frame store **250**. The reference frame may be, for example, a previously decoded INTRA-

coded frame, or a previously decoded INTER-coded frame. In either case, the region of pixels indicated by the reconstructed motion vector is used to form a prediction for the macroblock in question. More specifically, the motion compensated prediction block **240** forms an array of pixel values for each block of the macroblock by copying corresponding pixel values from the region of pixels identified by the motion vector. The prediction, that is the blocks of pixel values derived from the reference frame, are passed from motion compensated prediction block **240** to combiner **230** where they are combined with the decoded prediction error information. In practice, the pixel values of each predicted block are added to corresponding reconstructed prediction error values output by inverse DCT transformer **220**. In this way an array of reconstructed pixel values for each block of the macroblock is obtained. The reconstructed pixel values are passed to the video output **280** of the decoder and are also stored in frame store **250**. As subsequent macroblocks of the INTER-coded frame are decoded and stored, a decoded frame is progressively assembled in the frame store **250** and thus becomes available for use as a reference frame for motion-compensated prediction of other INTER-coded frames.

As explained above, in a typical video coding system, motion compensated prediction is performed on a macroblock basis, such that a macroblock is the smallest element of a video frame that can be associated with motion information. However, the video coding recommendation currently being developed by the Joint Video Team (JVT) of ISO/IEC MPEG (Motion Pictures Expert Group) and ITU-T VCEG (Video Coding Experts Group), allows motion information to be associated with elements smaller than a macroblock. In the following description, and throughout the remainder of the text, reference will be made to the version of this video coding standard described in the document by T. Weigland: "Joint Model Number 1", Doc. JVT-A003, Joint Video Team of ISO/IEC MPEG and ITU-T VCEG, January 2002, said document being included herein in its entirety. For simplicity, this version of the recommendation will be referred to as "JM1 of the JVT codec".

According to JM1 of the JVT codec, video pictures are divided into macroblocks of 16×16 pixels and are coded on a macroblock-by-macroblock basis. The coding performed follows the basic principles described above in connection with the generic video encoder and decoder of FIGS. **1** and **2**. However, according to JM1, motion compensated prediction of INTER coded macroblocks is performed in manner that differs from that previously described. More specifically, each of the macroblocks is assigned a "coding mode" depending on the characteristics of the macroblock and the motion in the video sequence. Seven of the coding modes are based on dividing a macroblock to be INTER coded into a number of sub-blocks, each comprising N×M pixels, and associating motion information with each of the N×M sub-blocks, not just with the macroblock as a whole. Each of the possible schemes for dividing a macroblock into N×M sub-blocks, provided by JM1 of the JVT video codec, is illustrated in FIG. **4** of the accompanying drawings. As can be seen from the figure, the possible divisions are: 16×16, 8×16, 16×8, 8×8, 4×8, 8×4 and 4×4. Thus, if the coding mode assigned to a particular macroblock is, for example, the 16×8 mode, the macroblock is divided into two sub-blocks of size 16×8 pixels each and both sub-blocks is provided with its own motion information. In addition, an eighth coding mode, known as SKIP (or skip) mode, is provided. If this mode is assigned to a macroblock, this indicates that the macroblock is to be copied from the reference video frame without using motion compensated prediction.

The decision relating to the choice of coding mode for a given macroblock is typically made as part of the motion estimation process. More specifically, in a video encoder such as that illustrated in FIG. **1**, but implemented to allow the use of different coding modes according to JM1 of the JVT codec, the motion estimation process performed by motion estimation block **130** is repeated for each possible division of the macroblock into N×M sub-blocks and for the skip mode. The motion estimation for the skip mode is a very simple one, since no motion search is needed, but a constant zero valued vector is assigned for this mode. For the rest of the INTER modes the motion is typically estimated by performing a block matching operation for each motion block inside the macroblock. After these operations, the mode that minimizes a certain cost function is selected for the macroblock. The cost function typically combines the prediction error with number of estimated bits needed to code the macroblock and thus measures the relative efficiency of each coding mode.

Because a video encoder operating in accordance with JM1 of the JVT codec assigns a particular coding mode to each macroblock that is INTER coded, it is necessary for a corresponding video decoder to be aware of that coding mode in order for it to correctly decode received information relating to the macroblock in question. Therefore, an indication of the coding mode assigned to each macroblock is provided in the video bit-stream transmitted from the video encoder to the video decoder. In order to minimise the amount of data required to indicate the coding modes, the coding mode for each macroblock is indicated using variable length coding. The codewords indicating the coding modes are assigned in such a way that the shortest codeword is used to represent the coding mode that is statistically most likely to occur. JM1 of the JVT codec uses a single set of so-called "Universal Variable Length Codes" (UVLC) to represent all syntax (data) elements in the video bit-stream and therefore this set of codewords is also used to represent the coding mode information for INTER coded macroblocks. The UVLC codewords used in JM1 may be written in the following compressed form, shown in Table 1 below, where the x_n terms take either the value 0 or 1:

TABLE 1

				1				
			0	x_0	1			
		0	x_1	0	x_0	1		
	0	x_2	0	x_1	0	x_0	1	
0	x_3	0	x_2	0	x_1	0	x_0	1

Scheme for Generation of UVLC Codewords According to JM1 of the JVT Codec

Table 2 presents the first 16 UVLC codewords, generated according to the scheme presented in Table 1.

Codeword Index	UVLC Codeword
0	1
1	001
2	011

TABLE 2

3	00001
4	00011
5	01001

TABLE 2-continued

6	01011
7	0000001
8	0000011
9	0001001
10	0001011
11	0100001
12	0100011
13	0101001
14	0101011
15	000000001
. . .	. . .

The First 16 UVLC Codewords of JM1 Generated According to the Scheme Presented in Table 1

JM1 of the JVT codec assumes that the skip mode is statistically the most likely coding mode for a macroblock. The number of skip mode macroblocks before the next macroblock with non-SKIP mode is indicated by a single UVLC codeword using Table 2 above. The remaining coding modes are represented by UVLC codewords as shown in Table 3 below:

TABLE 3

Macroblock Coding Modes of JM1

Codeword Index	Mode	UVLC Ccodeword
—	SKIP	Run-Length Coded
0	16 × 16	1
1	16 × 8	001
2	8 × 16	011
3	8 × 8	00001
4	8 × 4	00011
5	4 × 8	01001
6	4 × 4	01011

As previously described, the N×M modes in the table above indicate the size of the motion blocks.

A problem with the approach adopted in JM1 of the JVT codec is that the assumption that skip mode is always the most probable is not valid. If the video sequence contains global motion (panning, zooming, etc.), skip mode is actually never used. In these cases compression efficiency is seriously degraded, especially at lower bit-rates, since the codec is forced to use high overhead Mmacroblock coding modes.

Two prior art solutions for improving the coding efficiency of motion compensated prediction in the presence of global motion are known. The first of these is known as "global motion compensation" and is used, for example, in the ISO MPEG-4 and ITU-T H.263+ video coding standards. The second method is described in the document entitled "Global Motion Vector Coding" by Shijun Sun and Shawmin Lei, Doc. VCEG-20, ITU-T Video Coding Experts Group (VCEG) Meeting, Pattaya, Thailand 4-7 Dec. 2001, included herein by reference. The basic concepts of these two methods will now be briefly described.

As described in Annex P "Reference Picture Resampling" of International Telecommunications Union ITU-T Recommendation H.263 "Video Coding for Low Bit-Rate Communication", February 1998, the idea behind global motion compensation is to generate a reference frame for motion compensation that cancels the effects of global motion. In order to do this, complex operations are needed in the decoder to warp the reference frame into a more usable form. Furthermore, additional information has to be sent to the decoder to

guide the building of new reference frames for global motion compensation. More specifically, the global motion compensation scheme employed in the H.263 video coding standard uses a resampling process to generate a warped version of the reference frame for use in motion-compensated prediction of the current picture. This warped version of the reference frame may include alterations in the shape, size, and location with respect to the current picture. The resampling process is defined in terms of a mapping between the four corners of the current picture and the corresponding four corners of the reference frame. Assuming that the luminance component of the current picture has a horizontal size H and vertical size V, the mapping is performed by defining four conceptual motion vectors v^{00}, v^{H0}, v^{0V}, and v^{HV}, each conceptual motion vector describing how to move one of the four corners of the current picture in such a way as to map it onto the corresponding corner of the reference frame. This operation is illustrated in FIG. **5**. Motion compensated prediction for a macroblock of the current picture is then performed using block-matching with respect to the warped reference frame. This complicates the block matching process, as the value of each pixel of the warped reference frame used in the block matching process must be generated by mapping pixel values in the original (non-warped) reference frame into the co-ordinates of the warped reference frame. This is done using bilinear interpolation, which is a computationally intensive operation. The reader is referred to Annex P of the H.263 video coding standard for further details of the bilinear interpolation process used to generate the pixel values of the warped reference frame.

Global motion vector coding, as described in document VCEG-O20, referred to above, is a simplified version of global motion compensation. The reference frame is used as it is, but additional information is transmitted to describe the global motion and additional macroblock modes are used to indicate when global motion vectors are used. This approach is less complex than the global motion compensation technique just described, but there is additional encoder complexity associated with it. Namely, the encoder must perform extra motion estimation operations to find the global motion parameters and it also needs to evaluate more macroblock modes to find the optimal one. Moreover, the amount of extra global motion information that needs to be transmitted becomes large for small resolution video.

In view of the preceding discussion, it should be appreciated that there exists a significant unresolved technical problem relating to the coding of a digital video sequence in the presence of global motion, such as translation, panning or zooming of the camera. In particular, each of the three previously described prior art video coding solutions has some form of technical shortcoming. JM1 of the JVT codec, for example, has no special provision for taking account of global motion in video sequences. Therefore, when such motion is present it causes the video encoder to select macroblock coding modes that explicitly model the motion. This leads to a significant degradation in coding efficiency, as the global motion component is encoded in every INTER coded macroblock (or sub-block). The technique of global motion compensation (as provided by Annex P of the H.263 video coding standard) takes global motion into account by warping reference frames used in motion compensated prediction and therefore provides improved coding efficiency compared with a system in which no special measures are taken to code global motion. However, the warping process is computationally complex and additional information must be transmitted in the encoded video bit-stream to enable correct decoding of the video sequence. Although the related technique of global

motion vector coding is computationally less demanding than global motion compensation, it does involve a certain increase in encoder complexity and additional information must be still transmitted in the video bit-stream to enable correct decoding of the video data.

It is therefore one purpose of the present invention to combine the simplicity of local motion compensation with the coding efficiency of global motion compensation to yield a video coding system with significantly improved compression performance and a negligible increase in complexity.

SUMMARY OF THE INVENTION

In order to overcome, or at least mitigate to a large extent the problems associated with the coding of global motion in prior art video coding systems, the present invention is based on a redefinition of the skip mode concept used in JM1 of the JVT codec. The method according to the invention not only provides an improvement in coding efficiency in the presence of global motion (i.e. motion affecting the entire area of video frame), but also enables regional motion to be represented in an efficient manner.

According to the invention, the skip mode concept is redefined in such a way that a macroblock assigned to skip mode is either associated with a zero (non-active) motion vector, in which case it is treated in the same way as a conventional skip mode macroblock and copied directly from the reference frame, or it is associated with a non-zero (active) motion vector. The decision as to whether a macroblock should be associated with a zero or non-zero motion vector is made by analysing the motion of other macroblocks or sub-blocks in a region surrounding the macroblock to be coded. If it is found that the surrounding region exhibits a certain type of motion, a non-zero motion vector representative of that motion is generated and associated with the current macroblock. In particular, the continuity, velocity or deviation of motion in the surrounding macroblocks or sub-blocks can be analyzed. For example, if the motion in the surrounding region exhibits a certain level of continuity, a certain common velocity, or a particular form of divergence, a motion vector representative of that motion can be assigned to the current macroblock to be coded. On the other hand, if the region surrounding the current macroblock does not exhibit such continuity, common velocity or divergence and has an insignificant level of motion, the macroblock to be coded is assigned a zero motion vector, causing it to be copied directly from the reference frame, just as if it were a conventional SKIP mode macroblock. In this way, according to the invention, SKIP mode macroblocks can adapt to the motion in the region surrounding them, enabling global or regional motion to taken account of in an efficient manner.

In an advantageous embodiment of the invention, the surrounding macroblocks or sub-blocks whose motion is analysed are previously encoded macroblocks neighboring the macroblock to be coded. This ensures that motion information relating to the region the surrounding a macroblock is available in the encoder (decoder) when a current macroblock is being encoded (decoded) and can be used directly to determine the motion vector to be assigned to the current macroblock. This approach enables the motion analysis of the surrounding region performed in the encoder to be duplicated exactly in the decoder. This, in turn, means that according to the invention, no additional information must be sent to the decoder in order to model global or regional motion.

As will become apparent from the detailed description of the invention presented below, redefinition of the skip mode concept as proposed by the present invention has significant

technical advantages compared with the previously described prior art video coding methods. In particular, the method according to the invention enables global and regional motion within a video sequence to be taken account of in an efficient manner without the need for complex warping of the reference frame or any other computationally demanding operations. Furthermore, in contrast to both the global motion compensation and global motion vector coding methods previously described, no additional information must be transmitted in the video bit-stream to enable correct decoding of the video data. Additionally, a minimal amount of modification is required to incorporate the method according to the invention into existing video coding systems that employ the concept of skip mode macroblocks.

These and other features, aspects, and advantages of embodiments of the present invention will become apparent with reference to the following detailed description in conjunction with the accompanying drawings. It is to be understood, however, that the drawings are designed solely for the purposes of illustration and not as a definition of the limits of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic block diagram of a generic video encoder according to prior art.

FIG. **2** is a schematic block diagram of a generic video decoder according to prior art and corresponding to the encoder shown in FIG. **1**.

FIG. **3** illustrates the formation of a macroblock according to prior art.

FIG. **4** shows the 7 possible divisions of macroblocks into blocks according to JM1 of the JVT video codec.

FIG. **5** illustrates the generation of conceptual motion vectors for mapping the corners of a current picture to those of a reference picture in the global motion compensation scheme according to H.263 Annex P.

FIG. **6** is a schematic block diagram of a video encoder according to an embodiment of the invention.

FIG. **7** is a schematic block diagram of a video decoder according to an embodiment of the invention and corresponding to the encoder shown in FIG. **6**.

FIG. **8** illustrates encoding and decoding blocks for skip mode macroblocks in an encoder or decoder according an embodiment of the invention.

FIG. **9** shows an example of macroblock partitioning, motion in macroblocks surrounding a macroblock to be coded or decoded, and the generated skip mode motion vector for the macroblock (the darkened macroblock in the figure) according to an embodiment of the invention.

FIG. **10** is a schematic block diagram of a multimedia communications terminal in which the method according to the invention may be implemented.

BEST MODE FOR CARRYING OUT THE INVENTION

Exemplary embodiments of the invention will now be described in detail with particular reference to FIGS. **6** to **10**.

According to the invention, skip (or SKIP) mode macroblocks in a video coding system adapt to the motion of surrounding image segments. If active motion is detected around a macroblock to be coded/decoded, motion parameters conforming to the motion are generated and the macroblock is motion compensated. In this way, no additional information needs to be transmitted from the encoder to the decoder.

FIG. **6** is a schematic block diagram of a video encoder **600** implemented according to an embodiment of the invention. When encoding frames of a digital video sequence, encoder **600** operates in a manner similar to that previously described in connection with the prior art video encoder of FIG. **1** to generate INTRA-coded and INTER-coded compressed video frames. The structure of the video encoder shown in FIG. **6** is substantially identical to that of the prior art video encoder shown in FIG. **1**, with appropriate modifications to the motion estimation part necessary to implement the video encoding method according to the invention. All parts of the video encoder which implement functions and operate in a manner identical to the previously described prior art video encoder are identified with identical reference numbers.

As the present invention relates to the encoding of video frames in INTER-coded format and more particularly to details of the motion-compensated prediction performed as part of the INTER coding process, description of encoder **600** in INTRA-coding mode will be omitted and the following sections will concentrate on the operations performed by the encoder in INTER-coding mode.

In INTER-coding mode, the video encoder's control manager **160** operates switch **102** to receive its input from line **117**, which comprises the output of combiner **116**. The combiner **116** receives the video input signal macroblock by macroblock from input **101**. As combiner **116** receives the blocks of luminance and chrominance values which make up the macroblock, it forms corresponding blocks of prediction error information, representing the difference between the block in question and its prediction, produced in motion compensated prediction block **650**.

The prediction error information for each block of the macroblock is passed to DCT transformation block **104**, which performs a two-dimensional discrete cosine transform on each block of prediction error values to produce a two-dimensional array of DCT transform coefficients for each block. These are passed to quantizer **106** where they are quantized using a quantization parameter QP. Selection of the quantization parameter QP is controlled by the control manager **160** via control line **115**.

The quantized DCT coefficients representing the prediction error information for each block of the macroblock are then passed from quantizer **106** to video multiplex coder **170**, via line **125**. The video multiplex coder **170** orders the transform coefficients for each prediction error block using a zigzag scanning procedure, represents each non-zero valued quantized coefficient as a run-level pair and compresses the run-level pairs using entropy coding. Video multiplex coder **170** also receives motion vector information from motion field coding block **640** via line **126** and control information from control manager **160**. It entropy codes the motion vector information and control information and forms a single bit-stream of coded image information, **135** comprising the entropy coded motion vector, prediction error and control information.

The quantized DCT coefficients representing the prediction error information for each block of the macroblock are also passed from quantizer **106** to inverse quantizer **108**. Here they are inverse quantized and the resulting blocks of inverse quantized DCT coefficients are applied to inverse DCT transform block **110**, where they undergo inverse DCT transformation to produce locally decoded blocks of prediction error values. The locally decoded blocks of prediction error values are then input to combiner **112**. In INTER-coding mode, switch **114** is set so that the combiner **112** also receives predicted pixel values for each block of the macroblock, generated by motion-compensated prediction block **650**. The

combiner **112** combines each of the locally decoded blocks of prediction error values with a corresponding block of predicted pixel values to produce reconstructed image blocks and stores them in frame store **120**.

As subsequent macroblocks of the video signal are received from the video source and undergo the previously described encoding and decoding steps in blocks **104**, **106**, **108**, **110**, **112**, a decoded version of the frame is built up in frame store **120**. When the last macroblock of the frame has been processed, the frame store **120** contains a completely decoded frame, available for use as a motion prediction reference frame in encoding a subsequently received video frame in INTER-coded format.

The details of the motion-compensated prediction performed by video encoder **600** will now be described in detail.

Encoder **600** performs motion-compensated prediction in a manner similar to the previously described JVT codec. In other words, it is adapted to assign a coding mode to each INTER-coded macroblock depending on the characteristics of the macroblock and the motion in the video sequence being coded. When examining which coding mode to assign to particular macroblock, motion estimation block **630** performs a motion estimation operation for each coding mode in turn. Motion estimation block **630** receives the blocks of luminance and chrominance values which make up the macroblock to be coded for use in motion estimation via line **128** (see FIG. **6**). It then selects each of the possible coding modes one after the other, in turn, and performs motion estimation in order to identify a best match for the macroblock in the reference frame, on the basis of the selected coding mode and the pixel values of the macroblock to be coded. (The best match will comprise one or more best-matching regions of pixel values, depending on the coding mode). Each best-match is associated with an overall cost value, for example, a linear combination of the sum of absolute differences between the pixel values in the macroblock under examination and the best matching region in the reference frame, and an estimated number of bits required to code the mode and represent motion vectors. Once a best match has been obtained for each coding mode, motion estimation block **630** selects that coding mode which yields the smallest overall cost value as the coding mode for the current macroblock.

According to the invention, the coding modes used by encoder **600** correspond to those provided by JM1 of the JVT codec (shown in Table 3), with the exception that the SKIP mode is redefined to allow representation of global and regional motion. More specifically, the SKIP mode is modified in such a way that a zero (non-active) motion vector or a non-zero (active) motion vector is associated with each skip mode macroblock, depending on the characteristics of the motion in image segments surrounding the macroblock in question. In the following this type of motion vector will be referred to as a "skip mode motion vector".

When examining skip mode as part of the previously described motion estimation process performed in turn for each coding mode, the encoder first determines whether a zero or a non-zero skip mode motion vector should be used. To do this, the encoder is arranged to analyze the motion of image segments (e.g. macroblocks and/or sub-blocks) surrounding the macroblock to be coded. If it determines that the surrounding region exhibits a certain type of motion, for example it has characteristics indicative of global or regional motion, it generates a non-zero valued skip mode motion vector representative of the motion. On the other hand, if the encoder determines that the-region surrounding the current macroblock does not exhibit global or regional motion, but instead has an insignificant level of motion, it generates a zero valued skip mode motion vector. In other words, if the encoder determines that the motion in the region surrounding the current macroblock has a global characteristic, skip mode coding is adapted to take account of this (by generating an associated non-zero valued skip mode motion vector representative of the motion). Alternatively if no such motion is present, a zero valued motion vector is generated causing the skip mode as modified by the invention to operate in a conventional manner i.e. a zero valued skip mode motion vector causes a macroblock to be copied directly from the reference frame.

Having performed motion estimation operations for each of the available coding modes, including skip mode as modified according to the invention, encoder **600** determines which coding mode yields the smallest overall cost value and selects that mode as the coding mode for the macroblock in question. An indication of the finally selected coding mode, for example a variable length codeword selected from the set of codewords presented in Table 3, is associated with the macroblock and included in the video bit-stream **635**. This enables a corresponding decoder to identify the coding mode for the macroblock and correctly reconstruct the macroblock using the correct form of motion-compensated prediction.

The analysis of motion in a region surrounding a macroblock to be coded to determine whether a zero valued or non-zero valued skip mode motion vector should be used will now be considered in further detail with reference to FIG. **8** of the accompanying drawings. FIG. **8** illustrates the functional elements of the motion estimation block **630** associated with generating skip mode motion vectors. These include motion information memory **801**, surrounding motion analysis block **802**, active motion parameter generation block **803** and zero motion parameter generation block **804**.

The decision whether to generate a zero valued skip mode motion vector or a non-zero valued skip mode motion vector is made by surrounding motion analysis block **802**. The decision is made by analysing and classifying the motion of macroblocks or sub-blocks in a predefined region surrounding the macroblock to be coded using a predetermined analysis scheme. In order to perform the analysis, surrounding motion analysis block **802** retrieves motion information relating to the macroblocks and/or sub-blocks in the surrounding region from motion information memory **801**. Depending on the specific details of the implementation, surrounding motion analysis block may be arranged to analyze the continuity, velocity or deviation of motion in the surrounding macroblocks or sub-blocks. For example, if the motion in the surrounding region exhibits a certain level of continuity, a certain common velocity (as depicted in FIG. **9**, for example), or a particular form of divergence, this may suggest that some form of global or regional motion is present. As a consequence surrounding motion analysis block concludes that "active motion" is present in the surrounding region and a non-zero valued skip mode motion vector should be used. On the other hand, if the region surrounding the current macroblock does not exhibit such continuity, common velocity or divergence and has a generally insignificant level of motion, the surrounding motion analysis block concludes that "non-active motion" is present in the surrounding region and consequently a zero valued skip mode motion vector should be used.

As shown in FIG. **8**, if the surrounding motion analysis block determines that "active motion" is present in the surrounding region, it sends an indication to that effect to active motion parameter generation block **803**, which forms a non-zero valued skip mode motion vector representative of the motion in the surrounding region. To do this active motion